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DNB Performance

December 19, 2013

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Calvin Liang

Topics

- Highlights since provisional
- General DNB characteristics
- Radiometric sensitivity
  - Dynamic Range
  - SNR
- Radiometric Accuracy
  - Radiometric accuracy
    - Low gain stage (LGS) radiometric accuracy from direct lunar observation
    - High gain stage (HGS) radiometric accuracy from lunar illuminated ground scenes
    - Mid gain stage (MGS) radiometric accuracy inferred from calibration transfer uncertainty
  - Stray light and stray light correction

Highlights since provisional

- DNB stray light correction and associated flagging became operational
- DNB geolocation correction LUT resulted in excellent geolocation accuracy. (Already discussed under geospatial performance)
- DNB radiometric sensitivity characterized
  - Dynamic range and SNR
  - DNB gain transition anomaly
  - Photon transfer curve and measurements of read out noise, detector dark current noise and airglow
- DNB radiometric uncertainty characterized
  - Lunar calibration results for LGS compared favorably with MODIS and Seawifs
  - Vicarious calibration utilizing lunar illuminated playa characterized HGS performance

DNB Characteristics: meeting most performance requirements.

1. DNB Characteristics	Specification	Prelaunch Performance	On-orbit Performance
Spectral Passband center	700 ±14 nm	707 nm	Model estimate 694 nm [1]
Spectral Passband bandwidth	400 ±20 nm	379 nm	Model estimate 375 nm[1]
Horizontal Sampling Interval (HSI)	742 m (±5%)	742 m (±9%) scan 742 m (±7%) track	704-790 m (scan) 734-777 m (track)
Horizontal Spatial Resolution (HSR)	<= 800 m	< 820 m, scan < 670 m, track	< 770 m, <52º < 750 m, <52º
Geolocation uncertainty (3σ) on ellipsoid	400 m nadir 1500 m edge	N/A	249 m (nadir) 1041 m (edge)
Dynamic Range	3×10^{-9} $W\cdot cm^{-2}\cdot sr^{-1}$ – 0.02 $W\cdot cm^{-2}\cdot sr^{-1}$	3×10^{-9} $W\cdot cm^{-2}\cdot sr^{-1}$ – 0.021 $W\cdot cm^{-2}\cdot sr^{-1}$	3×10^{-9} $W\cdot cm^{-2}\cdot sr^{-1}$ – 0.0209 $W\cdot cm^{-2}\cdot sr^{-1}$
SNR @<53 deg SNR @ >= 53 deg	>=6 @ Lmin >=5 @ Lmin	>10 across scan	>9 across scan now >8 projected EOL
Calibration Uncertainty LGS[2]	5%/10% (0.5 Lmax/ transition to MGS)	3.5%	[4%,8%] (1 σ, ROLO) [-4%,2%] (1 σ, Modis)
Calibration Uncertainty MGS[2]	10%/30% (upper/ lower transition)	7.8%	[-7.7%, 5.7%] (1 σ, Modis)
Calibration Uncertainty HGS[2]	30%/100% (transition from MGS/ Lmin)	11%	15% (1 σ)[3] ; 10% [3,,4] 18.6% (1 σ) ; 11.8% [4] [2.8%, -15%] [3] ; [10%, -8.2%][3,4] [-0.8%, -18.6%] ; [6.4%, -11.8%][4]
Stray light	10% of minimum radiance	N/A	>100% Lmin ~15% Lmin after stray light correction

Red indicates JPSS L1 requirements

(1) Lei, N., Z. Wang, B. Guenther, X. Xiong, and J. Gleason (2012), Modeling the detector radiometric response gains of the Suomi NPP VIIRS reflective solar bands, *Proc. of SPIE* , **8533**, 853319.
(2) Radiometric uncertainty assumes signal with sufficient SNR. For per measurement uncertainty RSS with 1/SNR.
(3) Before Nov 16, 2012
(4) Inferred comparison with Modis

Radiometric Sensitivity

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Dynamic Range

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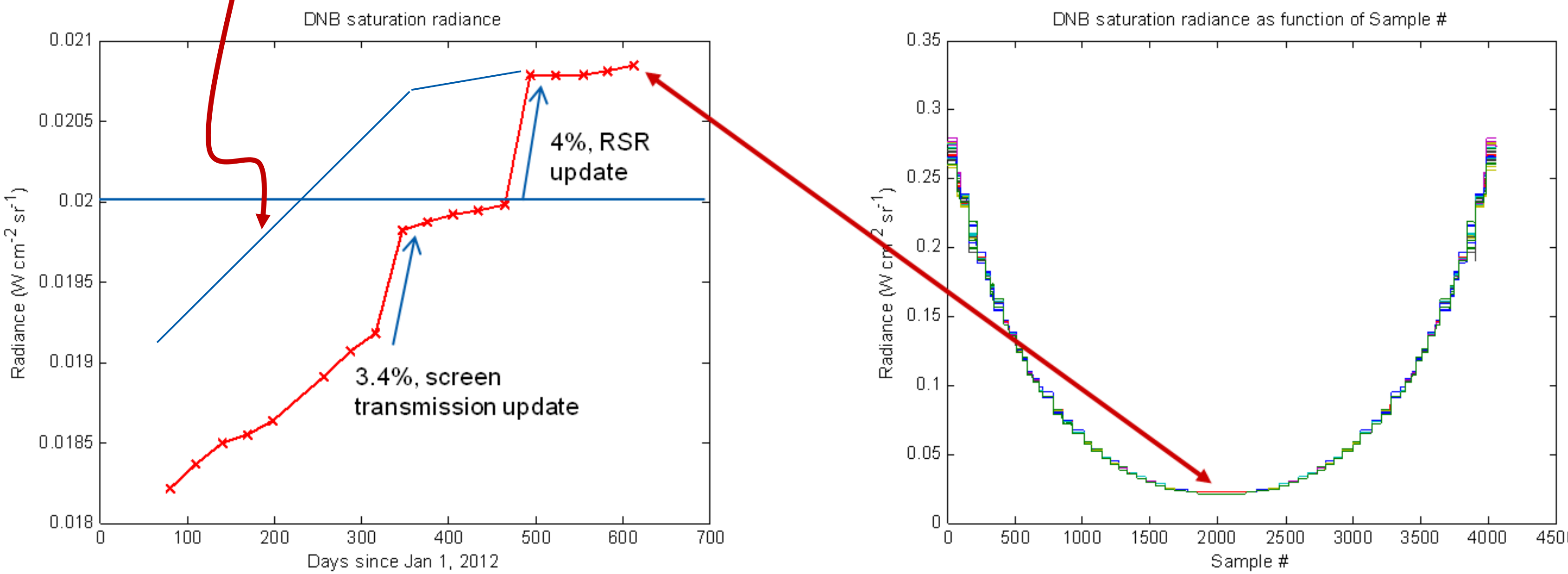
Approximate saturated radiance
if correct RSR and screen transmission
used at all times.



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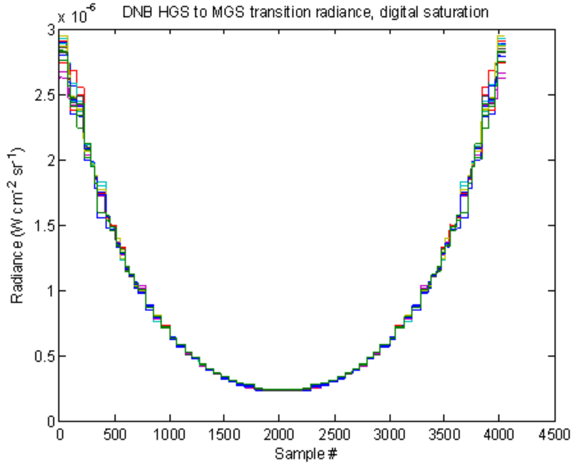
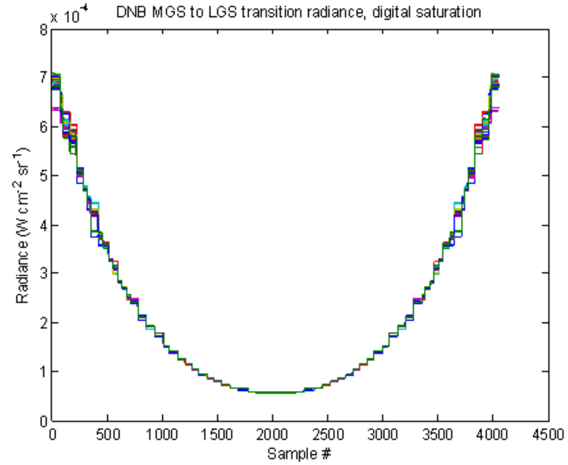
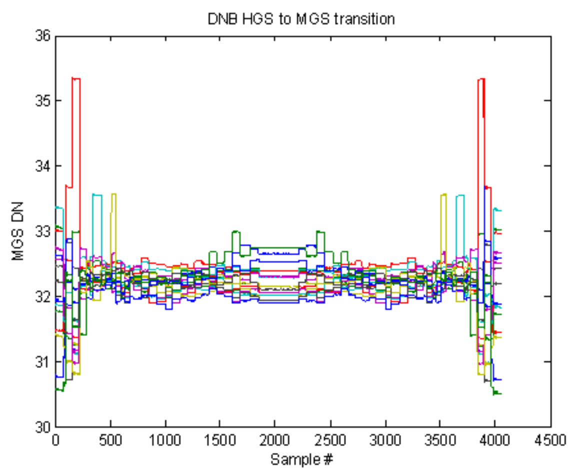
Due to aggregation scheme to keep a constant ground footprint, saturation radiance is a function of scan angle. As of September 2013, saturation radiance meets the requirement of 0.02 W·cm^{-2}·sr^{-1} .

Expected radiance and DNs at transitions







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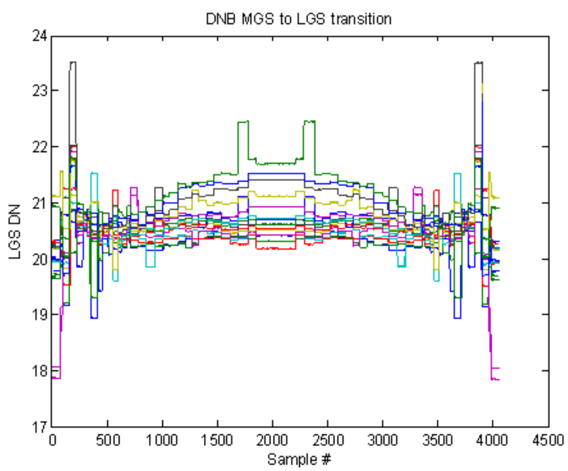
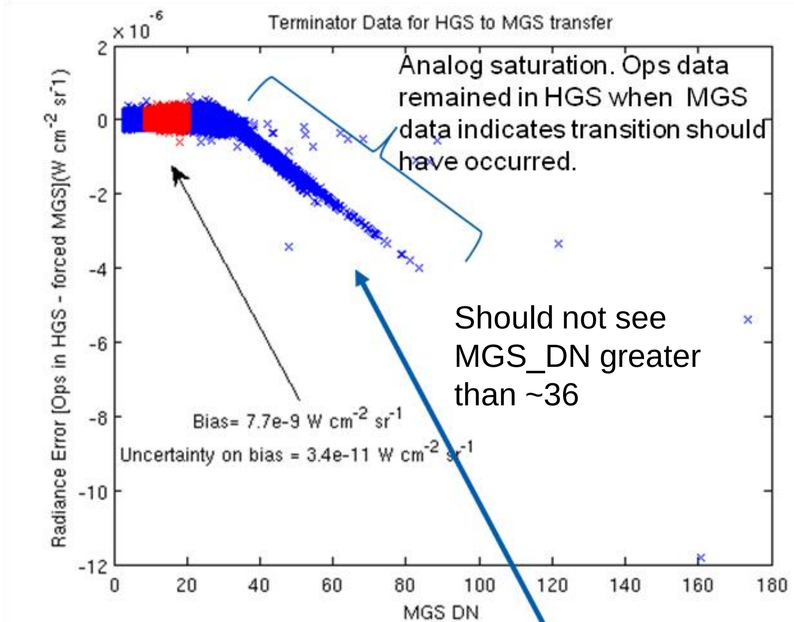
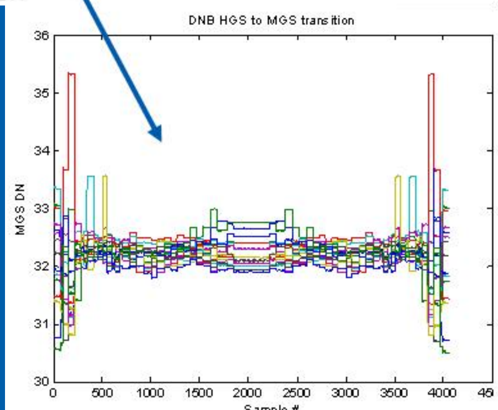
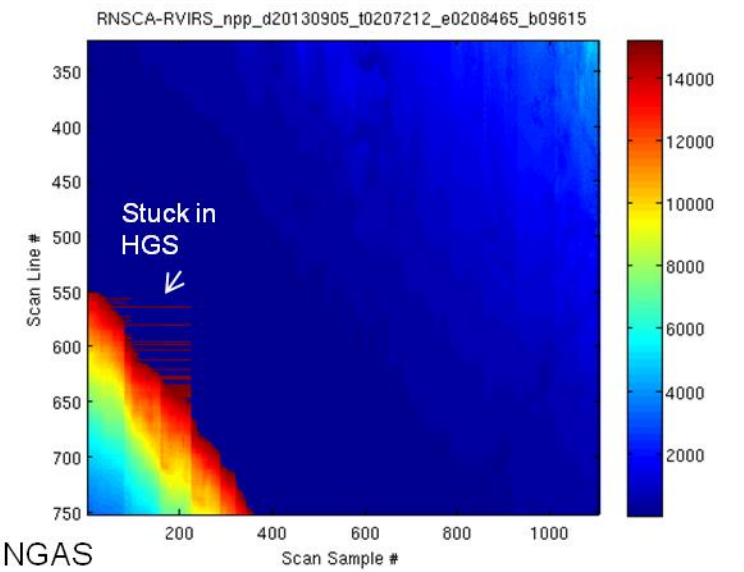


Due to aggregation scheme to keep a constant ground footprint, transition radiance values (between gain stages) are functions of scan angle. However, DNs at which transitions occur are roughly constant.

Analog saturation (late transition, DR 4603) observed







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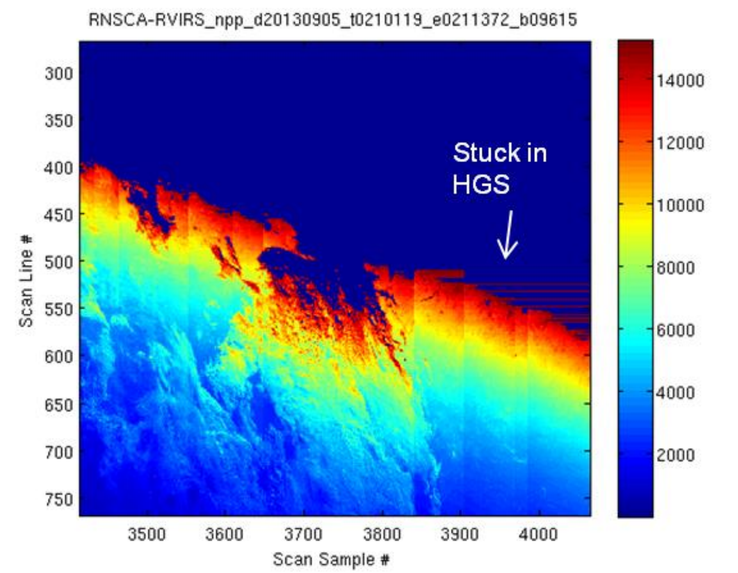

Analog saturation occurs mostly in aggregation zones 29-32. Some isolated pixels occur in other zones. If included in cross cal between stages, saturated pixels will bias c1 for higher sensitivity stages high. This results in higher retrieved radiance for all pixels in the affected aggregation zone. Furthermore, during normal ops, analog saturated pixels will retrieve lower radiance than actual radiance.

Early transition (DR 7364)

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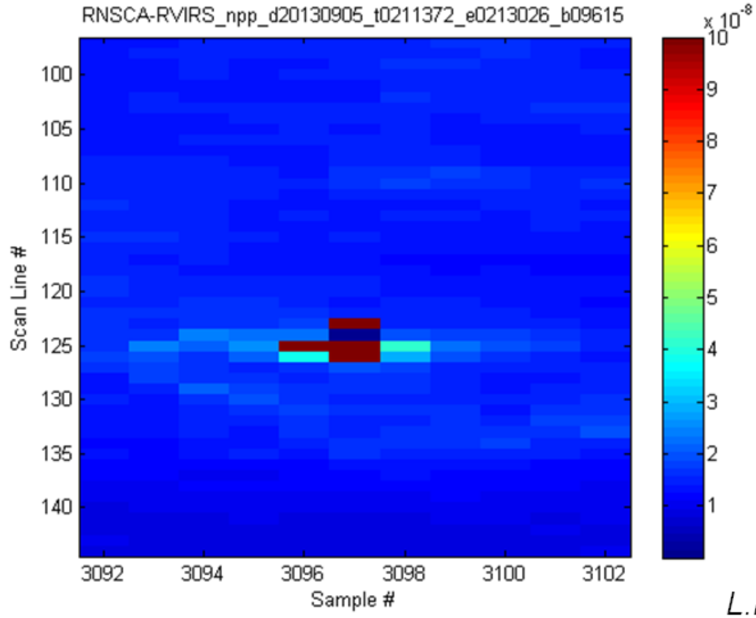

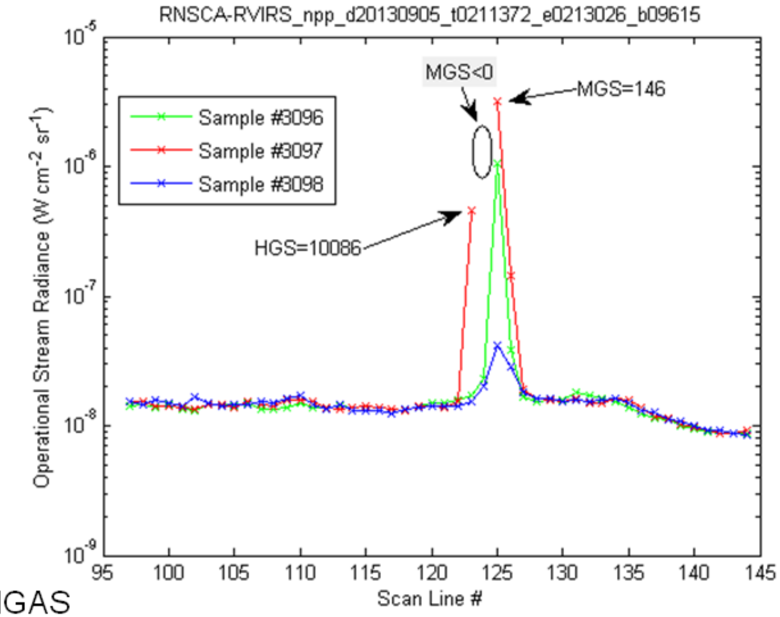

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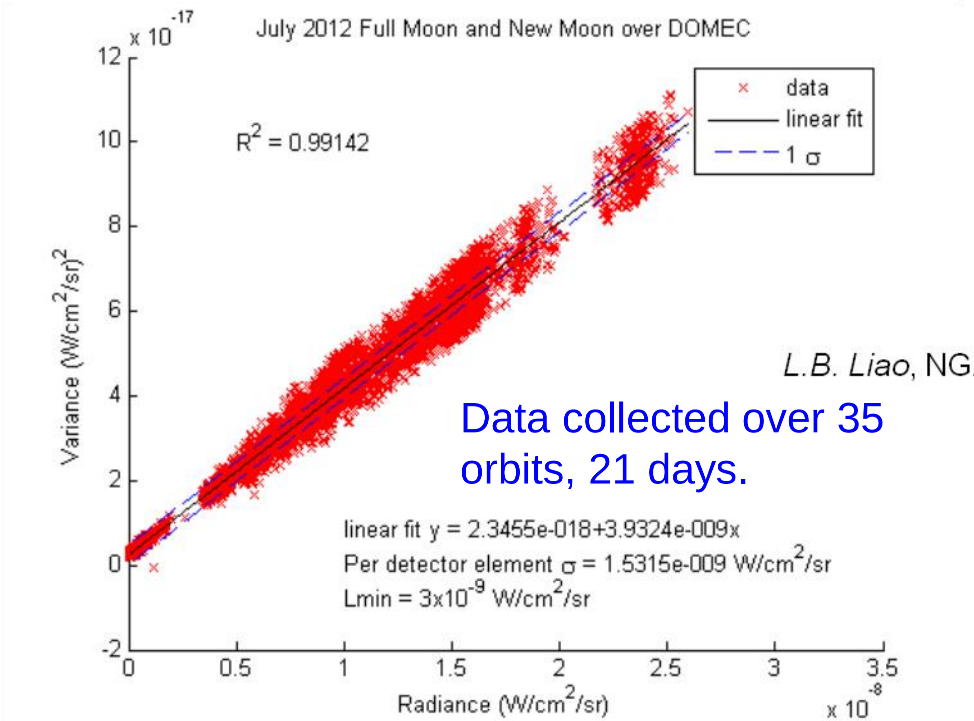
Sudden negative or extremely low radiance pixels observed within a bright patch. This is due to early transition from HGS to MGS. In some instances, truncation of the data results in negative MGS_dn. Recall that base on digital saturation consideration, transition is supposed to occur around 20-30 dn's. This is a hardware issue that will impact future DNB units.

Scene based determination of SNR using photon transfer curve (PTC) (1/2)



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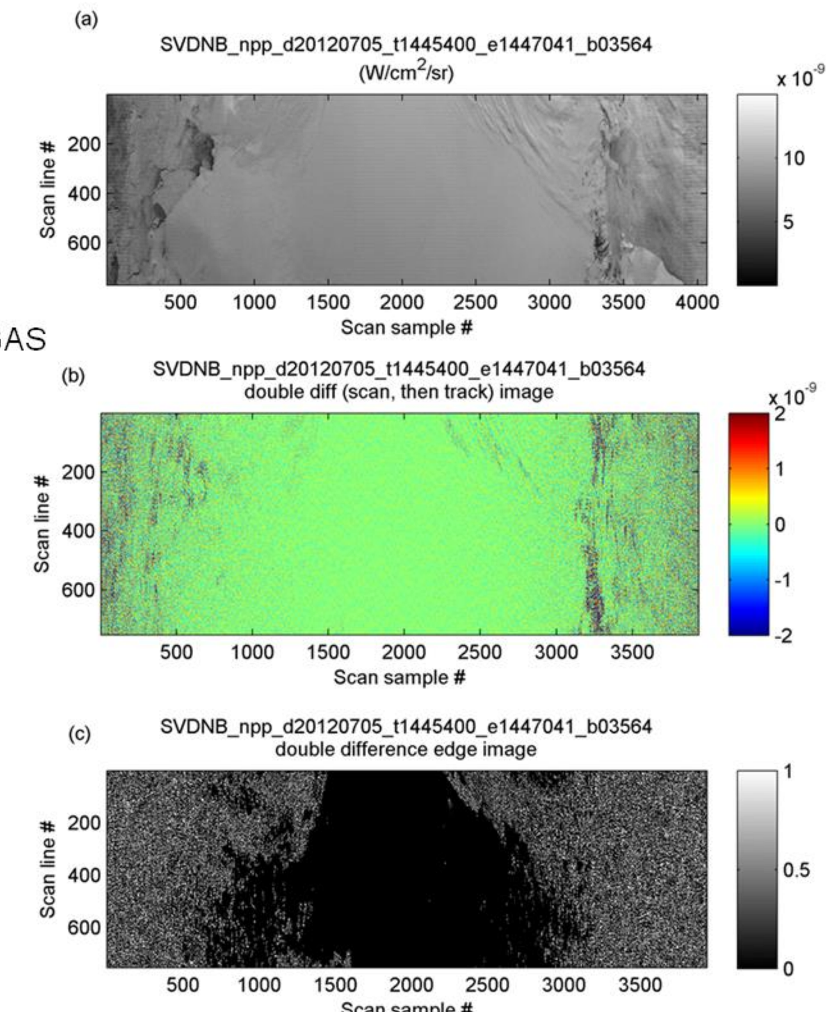
Data collected over 35 orbits, 21 days.

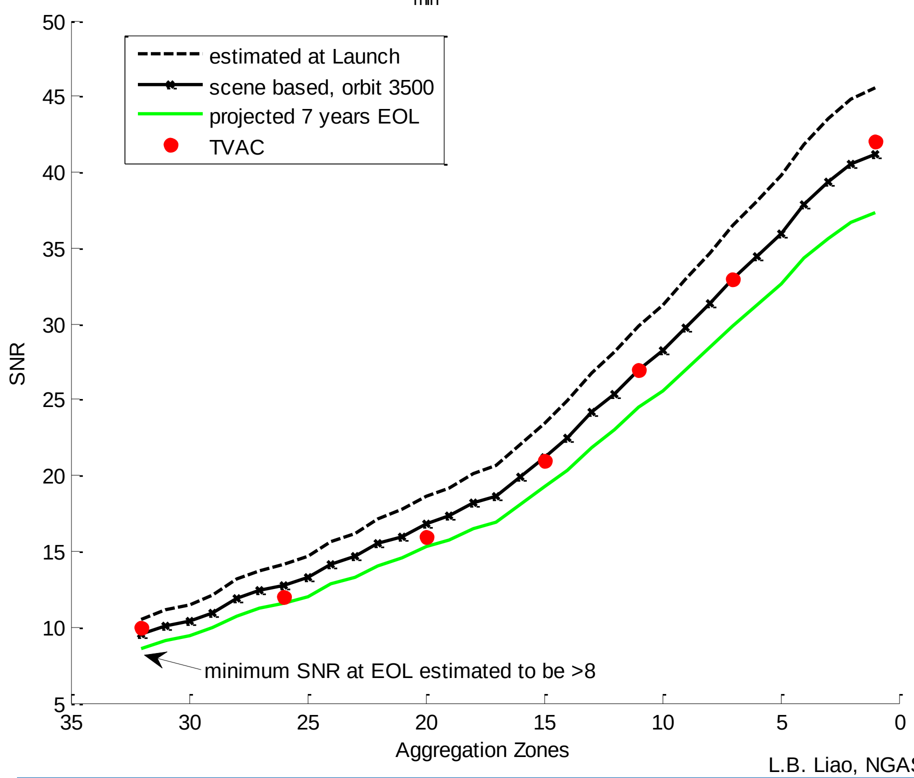


$$N_{agg} \times Var(L) - \left(\frac{1}{N_{agg}}\right)\underbrace{\left(\frac{G_e}{G_L}\sigma_{e^-,T}\right)^2}_{\text{aggregated read-out noise}} = \underbrace{\left(\frac{G_e}{G_L}\sigma_{e^-,S}\right)^2}_{\text{detector element dark current noise}} + \left(\frac{G_e}{G_L}\langle L\rangle\right)$$

In order for PTC to be valid, noise sources must add in quadrature and photon noise obey Poisson distribution. Thus we must remove other sources of noise via signal processing and image processing.

Scene based determination of SNR using PTC (2/2)

$$SNR = \frac{\sqrt{Var(L)}}{\langle L\rangle} = \frac{\sqrt{\left(\frac{1}{N_{agg}^2}\right)\left(\frac{G_e}{G_L}\sigma_{e^-,T}\right)^2 + \frac{1}{N_{agg}}\left(\frac{G_e}{G_L}\sigma_{e^-,S}\right)^2 + \frac{1}{N_{agg}}\left(\frac{G_e}{G_L}\langle L\rangle\right)}}{\langle L\rangle}$$



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Additional 10% degradation in response expected from July 2012 to EOL in 2017. Most degradation in SNR due to increase in dark current noise. We still expect SNR > 8 EOL.

Once derived, PTC can be used to predict SNR at any time and any radiance (within the linear range), provided that one can derived the temporal evolution function of various noise sources other than the photon shot noise.

Zero signal PTC (from calibration views) can be used to derive dark current noise and readout noise

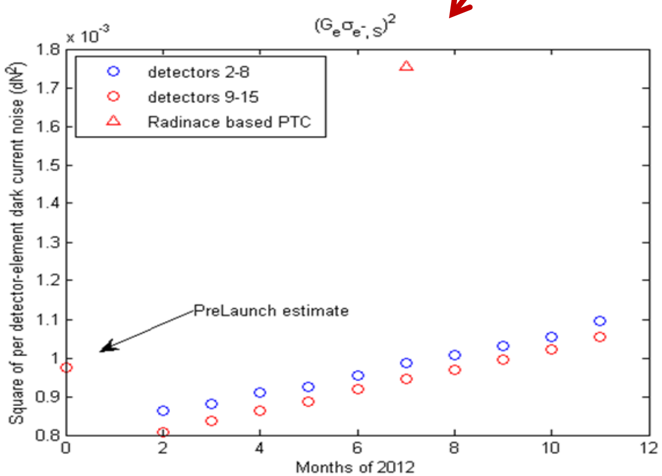
When observing a perfectly dark scene, the PTC for DNB can be written as,

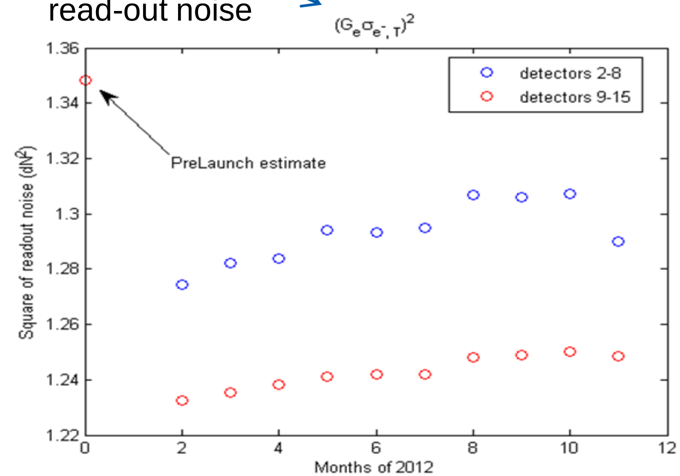
$$Var(HGSdN_s) = N_{agg} \times \left(G_e \sigma_{e^-,S}\right)^2 + \left(G_e \sigma_{e^-,T}\right)^2$$

Plot of variance of HGSDN versus N_{agg} results in intercept of read out noise and slope of dark current noise.

detector element dark current noise

aggregated read-out noise





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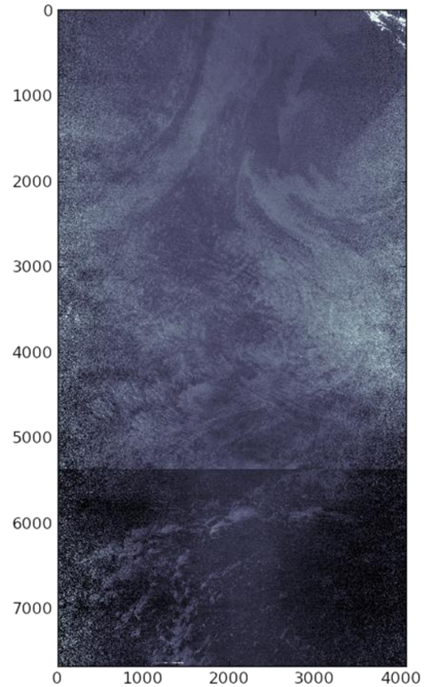
Dark current noise increasing with time (radiation exposure). We can use this time dependence to get EOL dark current noise.

Readout noise is relatively stable.

Zero signal PTC combined with finite signal PTC can be used to derive signal level in the presence of an unknown offset

- DNB calibration is conceptually simple.
  - Linear calibration means L = c1*(DN-DN0)/RVS.
  - c1 for low gain stage (LGS) is derived from solar diffuser data.
  - c1 for other gain stages (MGS and HGS) requires transfer from LGS using simultaneous observations around terminator region.
  - DN0 unfortunately can not be determined from the calibration views due to offsets that are expected to change with FPA temperature and possibly amount of radiation damage.
- DN0 determined for each detector, mirror side and sample number monthly.
  - Assumes that new moon data over the ocean are completely dark.
  - There are two parts to the offset: on-board offset which is applied on-board and the ground offset which applied by the IDPS to the transmitted HGSdN.
  - Only the ground offset is updated monthly.



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•Granules used in DN0 calculation for April 21, 2012.

•Obviously not dark. Contains signal from airglow.

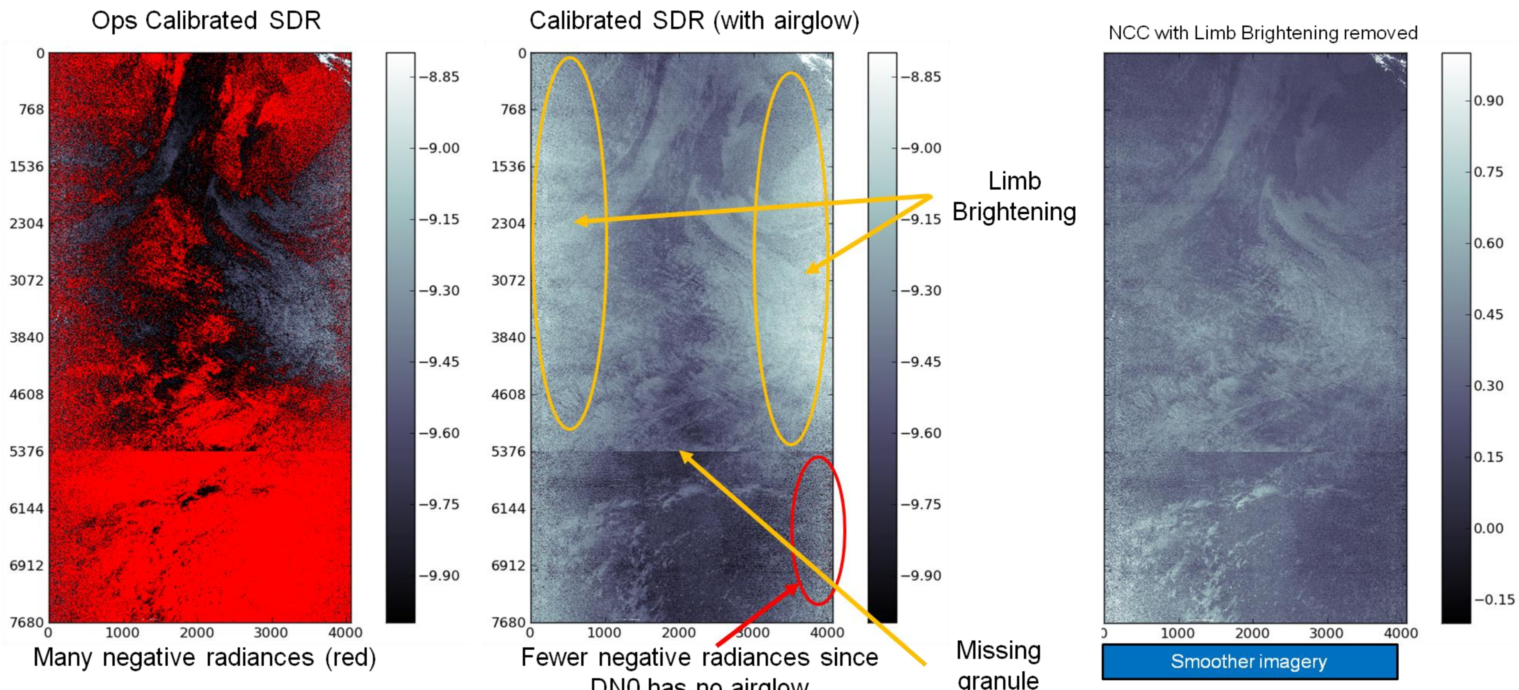
•How to calculate the magnitude of this signal if we don't know the offset?

Two approaches:

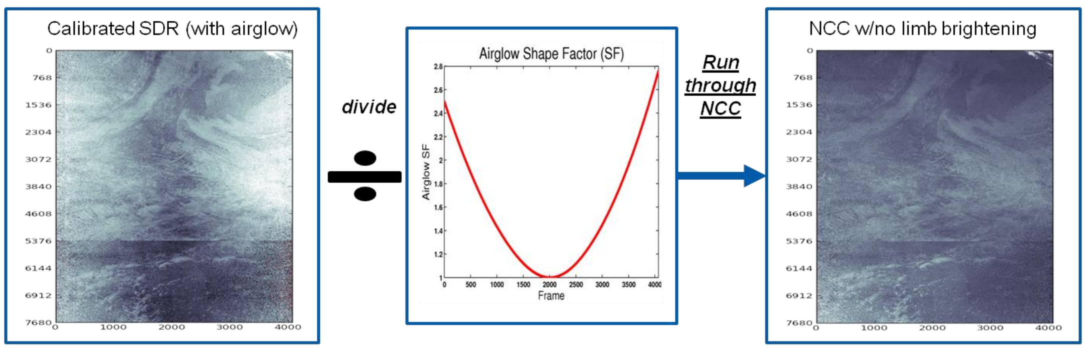
1. Use combined PTC approach.
2. Use pitch maneuver data to get true 'dark' and assume the relative offset between earth view and black body view stays constant to propagate dark to future time. Proposed by Shihyan Lee and implemented in RSB_autocal.

DN0_true(t, aggregation zone) = BlackBodyView(t, aggregation zone) – [BlackBodyView(Feb 2012, aggregation zone)-DN0_true(Feb 2012, aggregation zone)]

Airglow corrected SDR shows limb brightening which can be corrected for NCC with the derived airglow curve



C. Liang NGAS



Example application from April 21,2012

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Radiometric Accuracy

and Stray light

Lunar Cal for LGS

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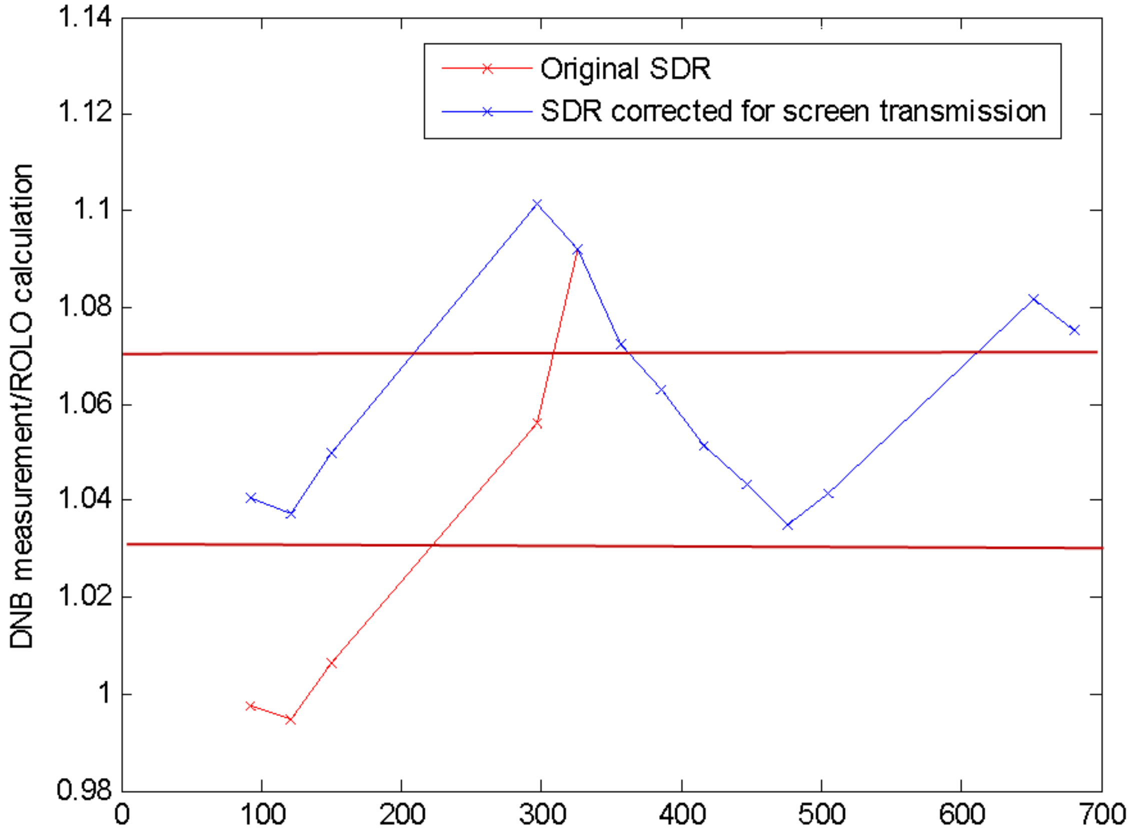

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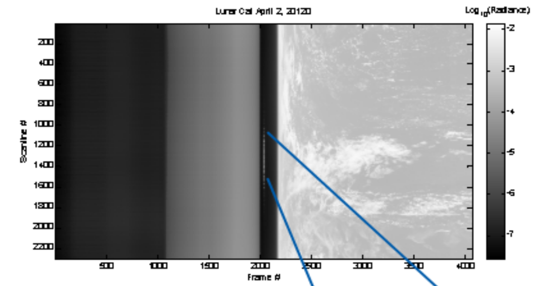

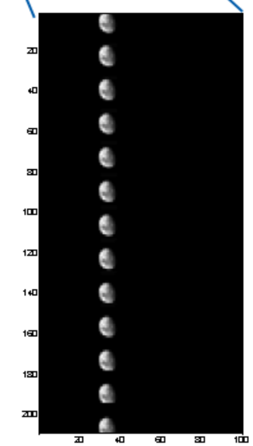

Estimated MODIS Aqua +7% (1)

Estimated Seawifs +2.8% (1)

(1) Eplee, et al Proc. of SPIE Vol. 8866 88661L-1

Radiometric uncertainty relative to ROLO is 6% ± 2%.
Relative to MODIS, this would translate to -1% ± 3%

Vicarious Cal of HGS data with lunar illuminated playa

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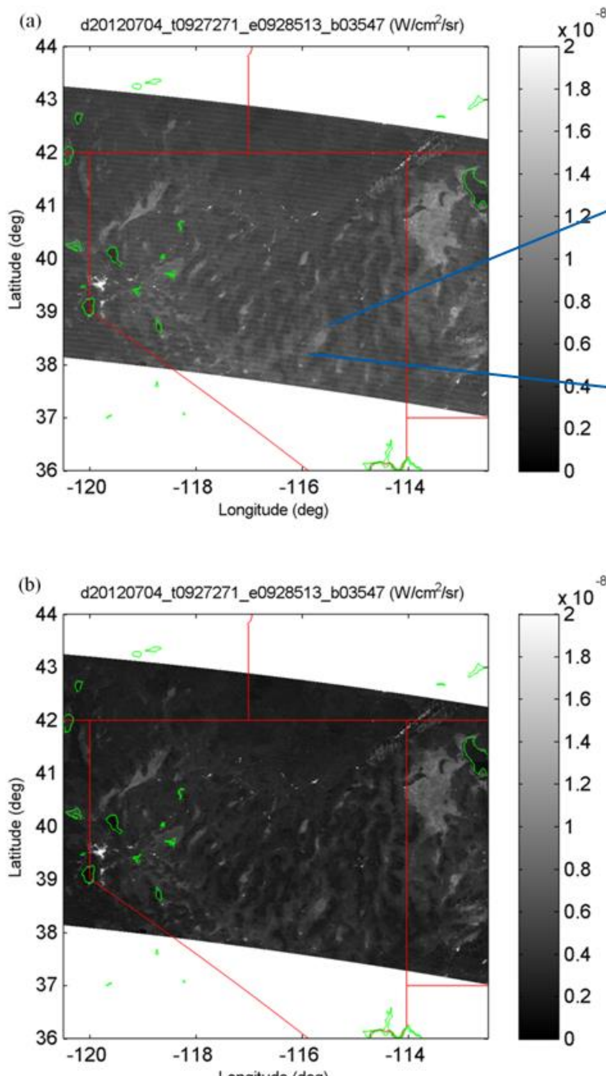
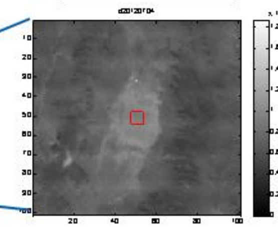
Before stray light removal



After stray light removal



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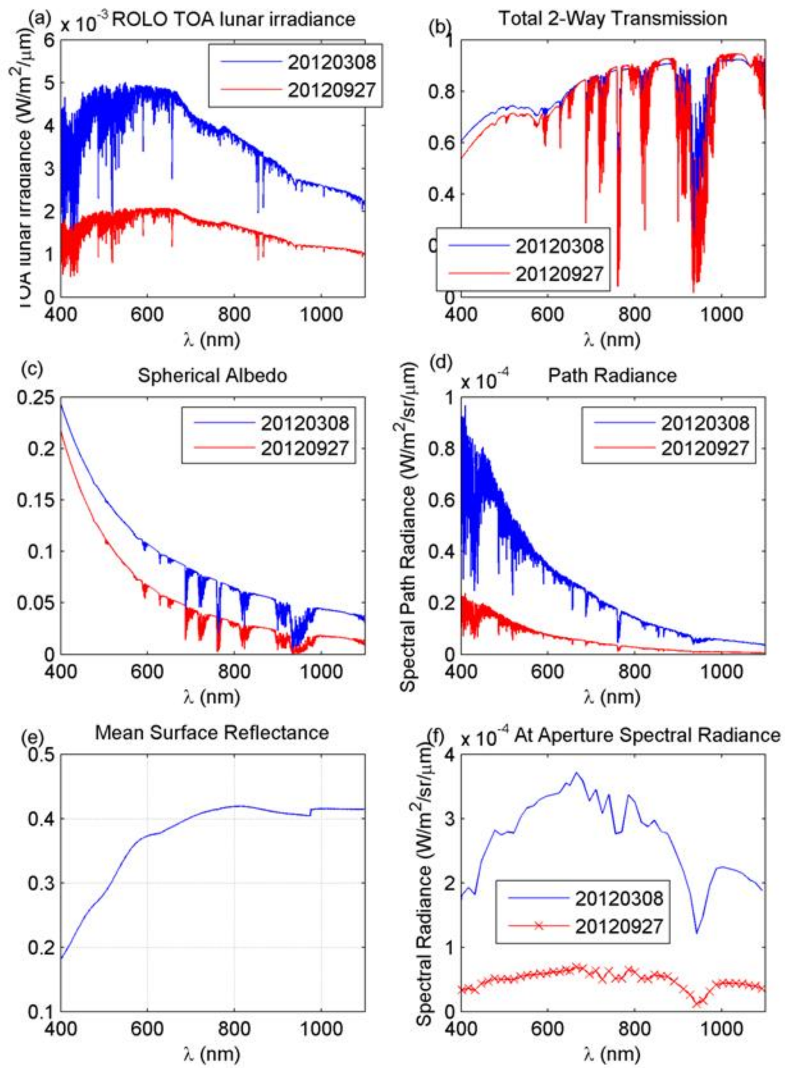
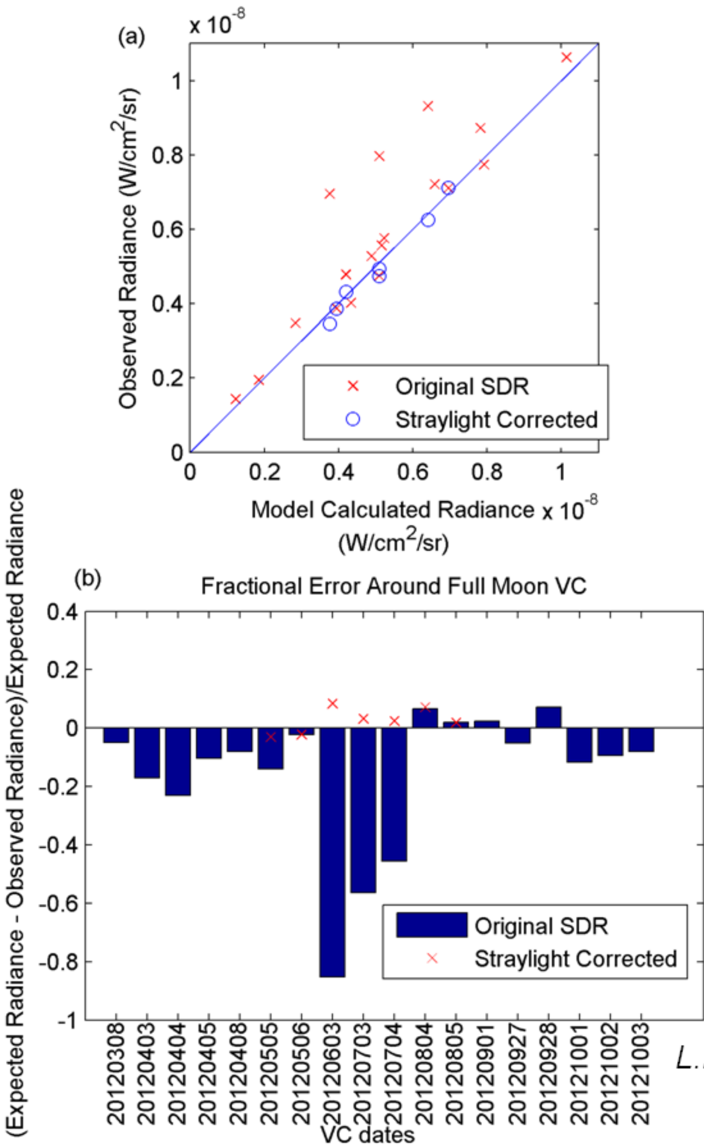


Results of 2012 HGS vicarious calibrations



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Radiometric Uncertainty (1 σ) (*)		
	Before Nov 16, 2012	After Nov 16, 2012
Relative to ROLO (ROLO-DNB)/ROLO	-6.1 ± 8.9 %	-9.7± 8.9 %
Relative to MODIS (MODIS-DNB)/MODIS	0.9 ± 9.1 %	-2.7± 9.1 %

(*) Note that sign is reversed from LGS uncertainty. Negative bias means DNB is retrieving higher radiance thank the reference.

Estimated calibration transfer uncertainty is 6.4% per transfer, implying MGS uncertainty of -1%± 6.7%. (MGS uncertainty is quoted with same sign as LGS)

	Stray light contamination
Before Correction	2.4×10^{-9} W·cm^{-2}·sr^{-1} (~100% L_{min})
After Correction	4.5×10^{-10} W·cm^{-2}·sr^{-1} (~15% L_{min})

DNB Stray Light Summary Description

- Stray light appears on the night side of the terminator
  - Occurs for both the northern & southern terminator crossing
  - Affects different segments of the orbit in the northern and southern hemispheres
  - Stray light has detector dependence
  - Level of stray light changes with scan angle, but extends across the entire scan

- DR 7060 implemented a look-up table (LUT) based process that applies correction factors to the DNB radiance values and flags the impacted data.

d20120915_t0126328_e0129224

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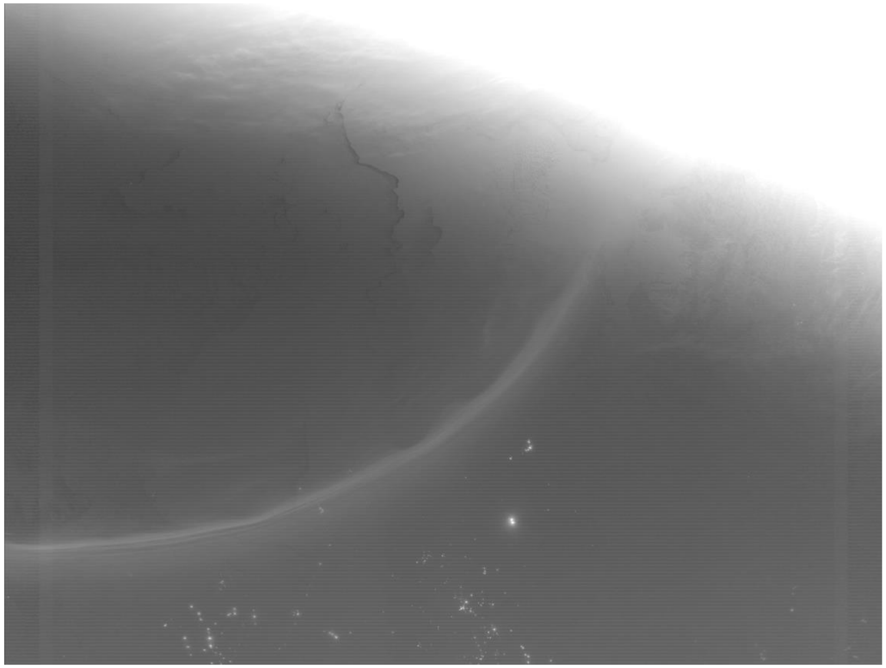
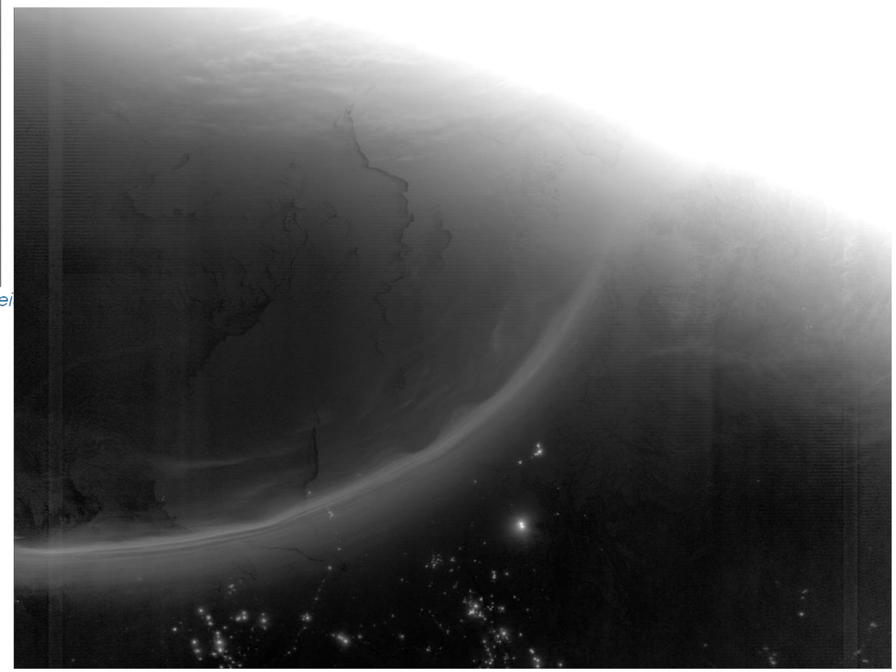
Northern Hemisphere (log scale)

d20130310_t2138151_e2143537



S. Wei

d20130310_t2138151_e2143537



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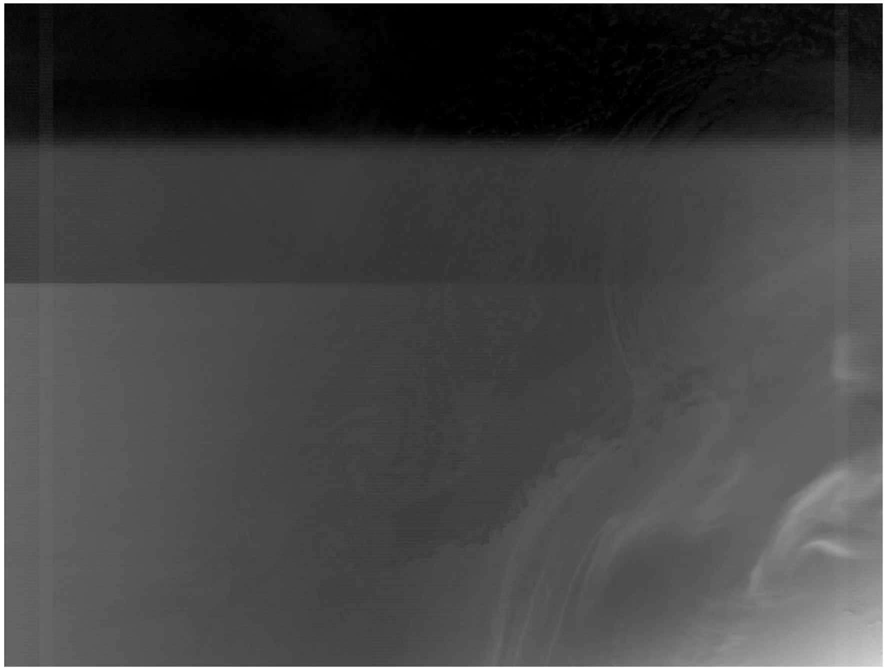
The stray light correction enhances the dynamic range of the scene and allows users to extract details that were previously washed out due to the stray light.

Southern Hemisphere (log scale)

d20130310_t2218047_e2223451



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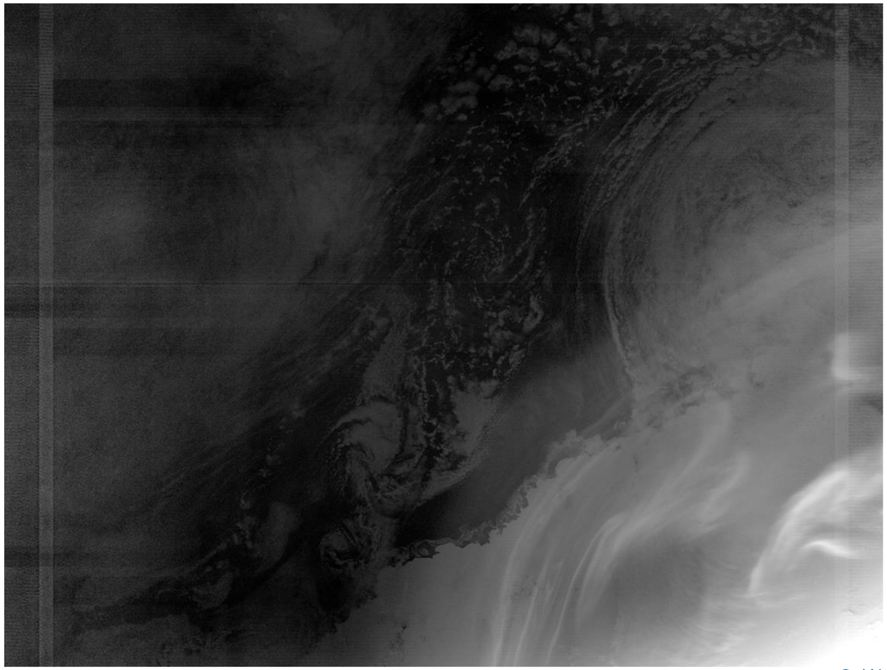
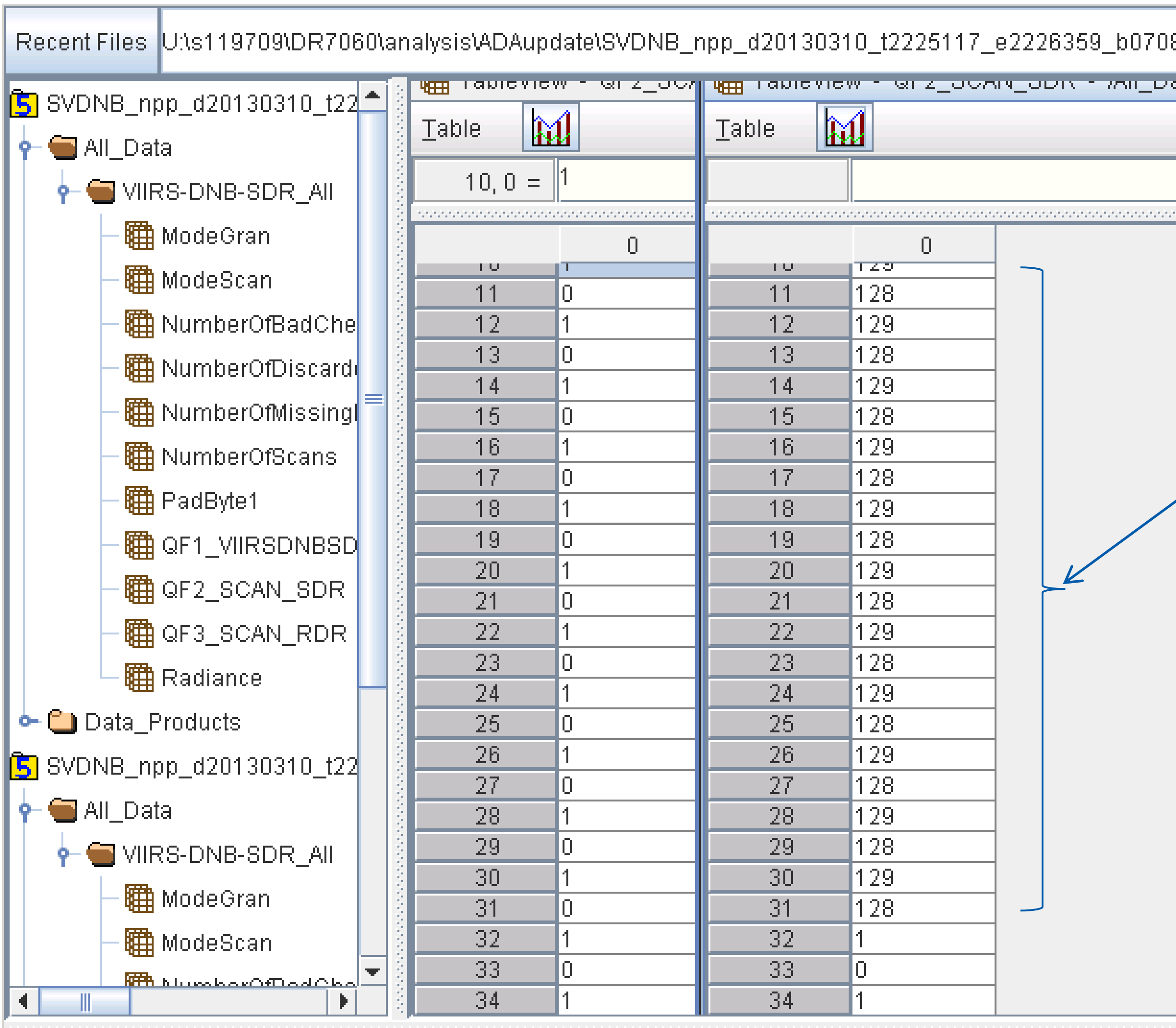
d20130310_t2218047_e2223451



S. Weiss, NGAS

The stray light correction enhances the dynamic range of the scene and allows users to extract details that were previously washed out due to the stray light.

DNB Scan Level Flagging Results



- HDF viewer tool Baseline ADA vs. DR7060 ADA QF2 Scan level flag shows new bit 7 stray light flag

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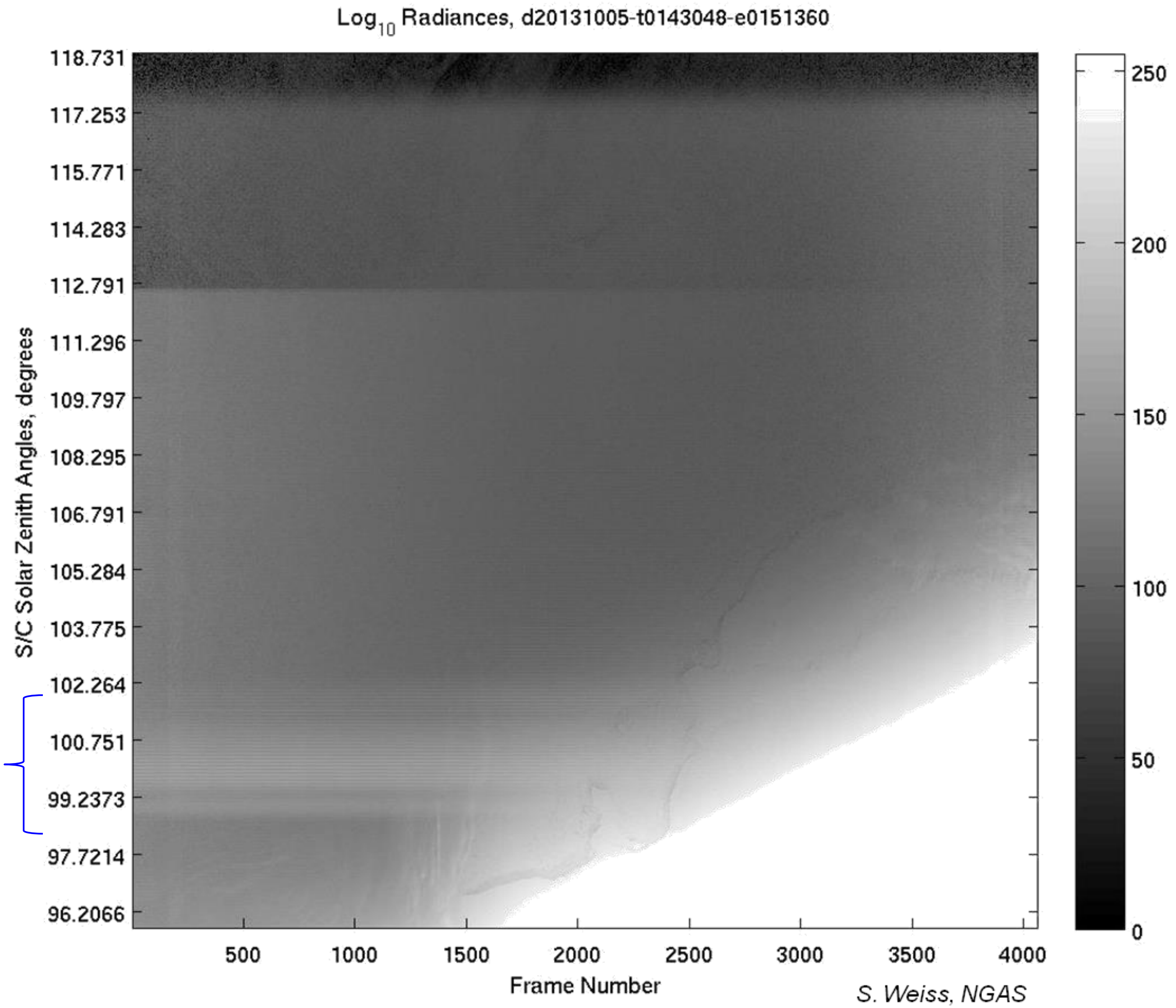
Stray light Correction Issues

- Additional stray light region shows up from October through December in the southern hemisphere
  - Ranges from about ~102.4 to ~98.8 degrees, depending on the month
  - Has a dependence on S/C solar zenith angle and detector
- Existing stray light correction scheme does not correct for this additional stray light region
  - Pattern shifts between the months, making it difficult to model and correct

Uncorrected Radiances for Oct 2013 - Additional Stray Light Region Near Terminator



Additional stray light region ranges from S/C Solar Zenith Angles of about 102.6° to 98.7° for Oct 2013

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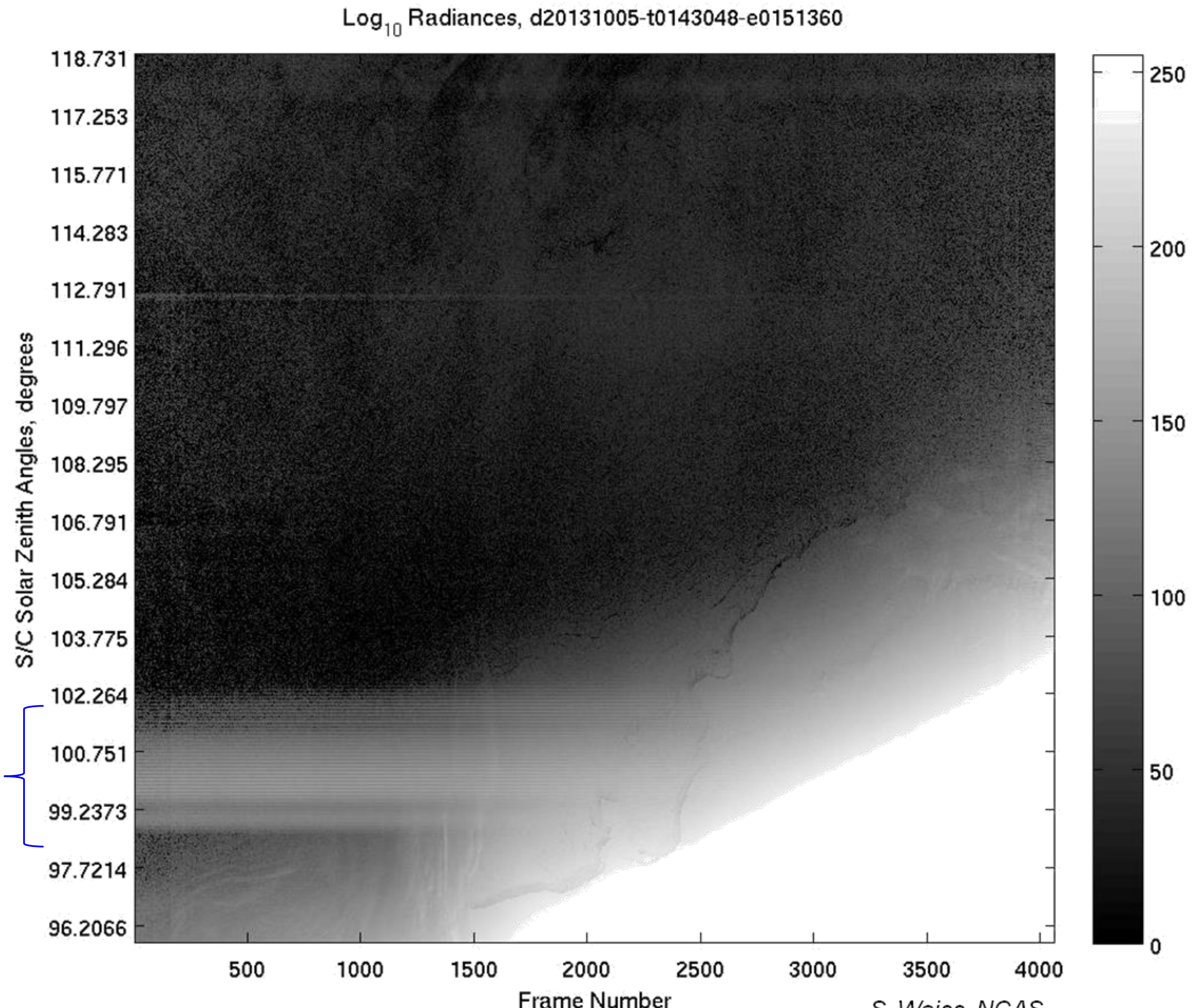
Corrected Radiances for Oct 2013 - Additional Stray Light Region Not Corrected

Additional stray light is not corrected by the stray light correction since this region is not modeled.



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Conclusions and Potential Improvements

- DNB has been demonstrated to meet most of its performance requirements. It has been characterized sufficiently to achieve the calibrated/validated status.
- Stray light correction has vastly improved the usability of the DNB night time data near the terminator
- It has been shown that zero signal PTC can be used to monitor change in dark current noise and SNR throughout the life of the mission. (As well as monitoring possible change in electronic gain and read out noise all of which should be fed back to JPSS-1.)
- Combined PTC scheme has been demonstrated to retrieve accurate airglow signal for data from the time period near the pitch maneuver.
- Potential Improvements:
  - Analyze the additional small stray light region appearing from October to December in the southern hemisphere. The stray light pattern for this region changes from month to month and may be difficult to model and correct.
  - More vicarious calibration data to quantify residual radiometric error after DNB stray light removal.
  - Develop a scheme for flagging 'dark' pixels described in DR7364. Detailed analysis showing frequency of occurrence as function of detector # and aggregation zones will help JPSS-1 DNB build.
  - Develop a scheme for flagging analog saturation and verify that these points are not included in cross calibration.
  - Use combined PTC scheme to validate the assumption that the offsets between earth view samples and black body view samples are constant.
  - Combined PTC can be used to remove limb brightening in NCC products once RSB_autocal is operational.

Backup

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Change in RSR and its impact on in-band radiance

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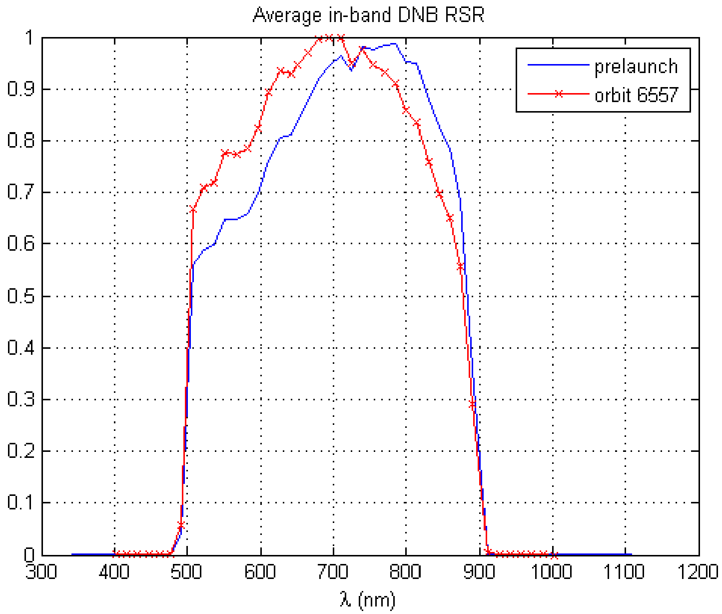
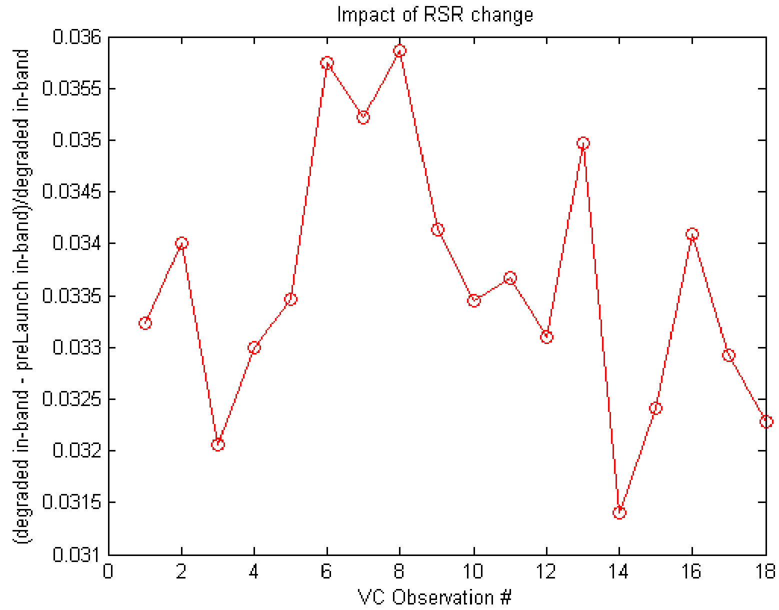
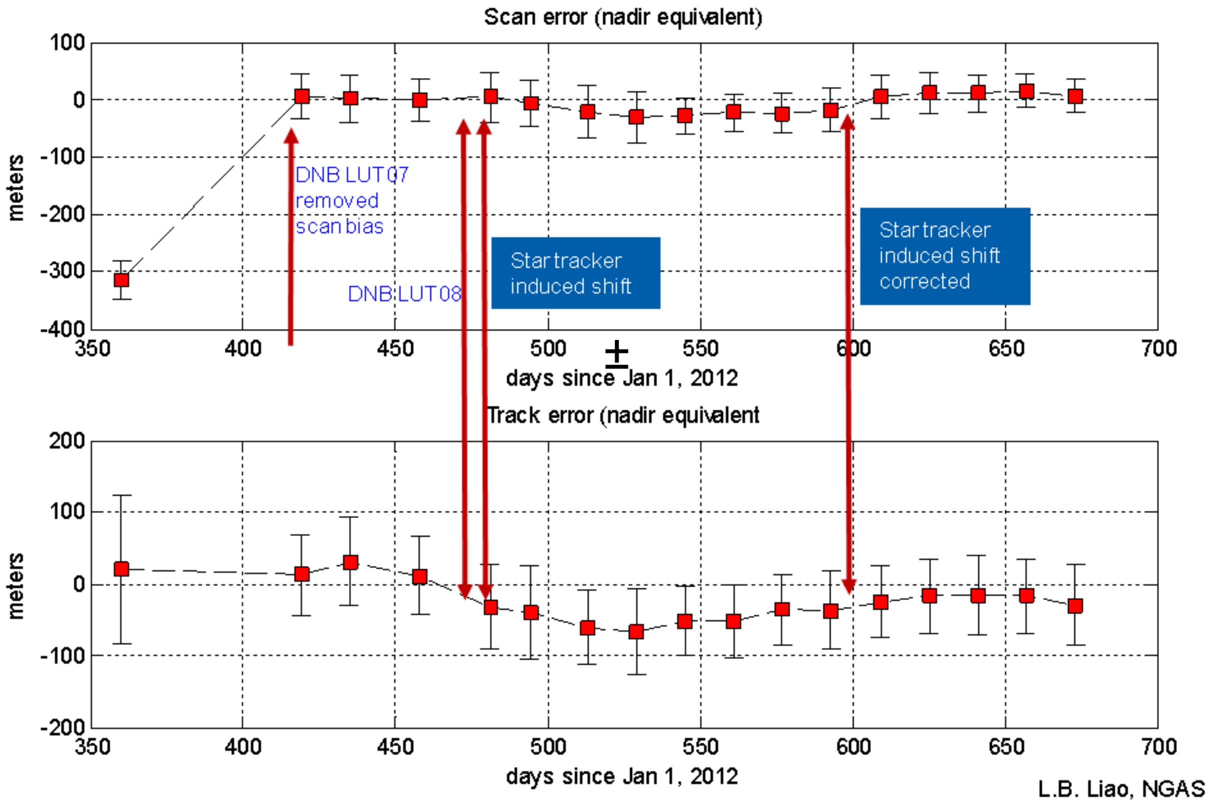




DNB Geolocation



As of Nov 4, 2013, the DNB geolocation accuracy is,
Scan : 8 ± 33 μrad ; Track : -35 ± 68 μrad

DNB spatial characteristics

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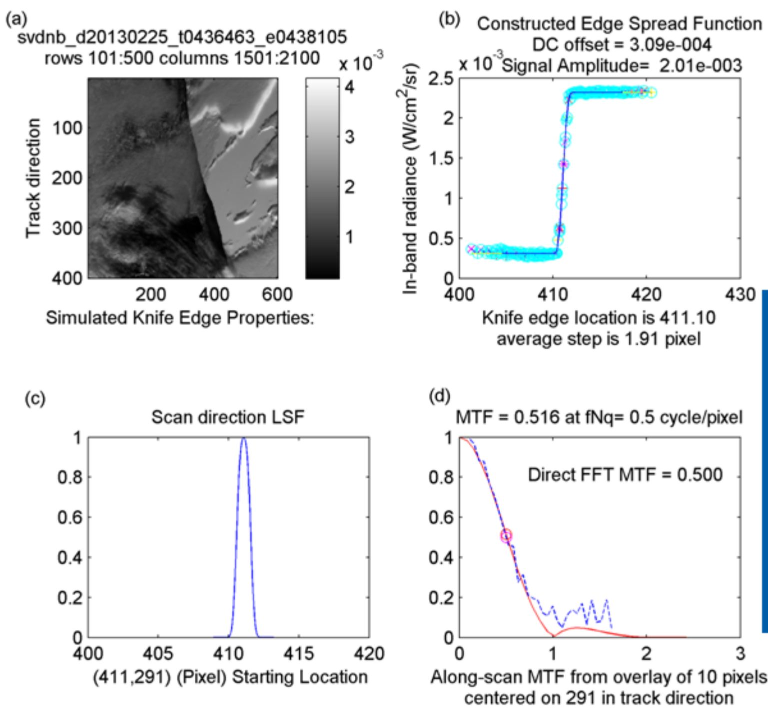
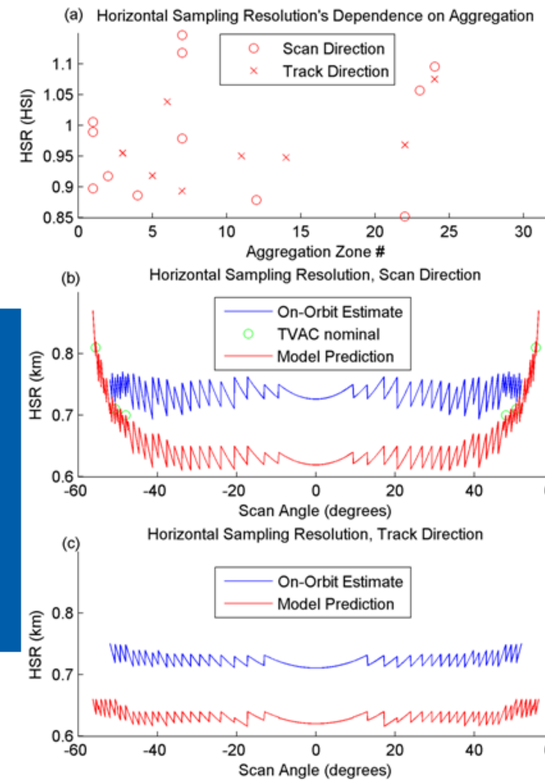


Model based line spread function (LSF) construction using ice edge scenes was utilized to retrieve horizontal sampling resolution (HSR). Correction for edge slant was performed in Fourier space.



L.B. Liao, NGAS

DNB HSR is approximately a constant multiple of the horizontal sampling interval (HSI) for aggregation zones 1-24. This results in approximately constant HSR in units of ground distance, with saw tooth pattern that is inherent in the ground HSI. HSR meets the requirement of 800 meters upto scan angle of 52 degrees.

Combined PTC approach derives photon signal from variance values, eliminating the need to know the offset

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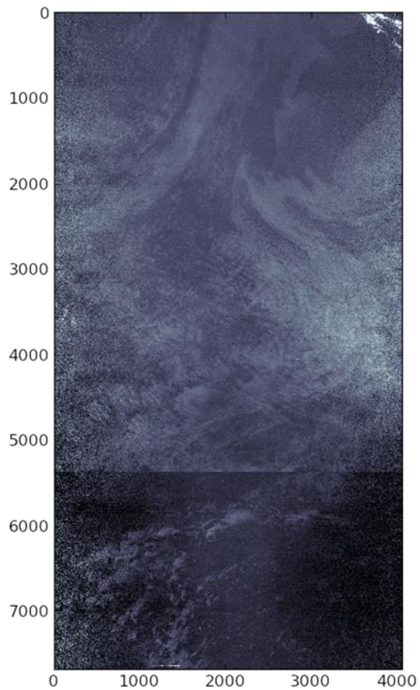
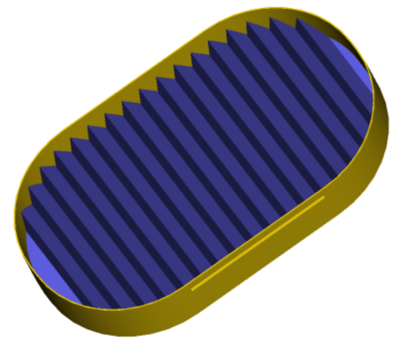
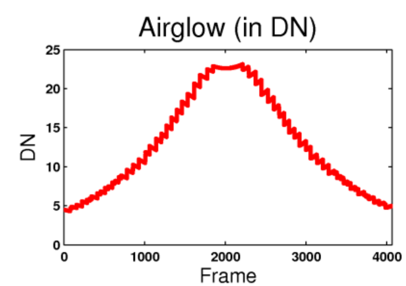


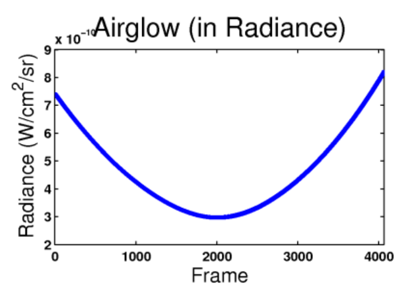
Calvin Liang, *NGAS*

$$Var(HGSdN_{EV}) = N_{agg} \times \left(G_e \sigma_{e^-,S}\right)^2 + G_e \langle HGSdN_{EV} \rangle + \left(G_e \sigma_{e^-,T}\right)^2$$



$$Var(HGSdN_{OBCBB}) = N_{agg} \times \left(G_e \sigma_{e^-,S}\right)^2 + \left(G_e \sigma_{e^-,T}\right)^2$$





$$HGSdN_{EV} = \frac{Var(HGSdN_{EV}) - Var(HGSdN_{OBCBB})}{G_e}$$

Uncorrected Radiances for Nov 2013 - Additional Stray Light Region Near Terminator

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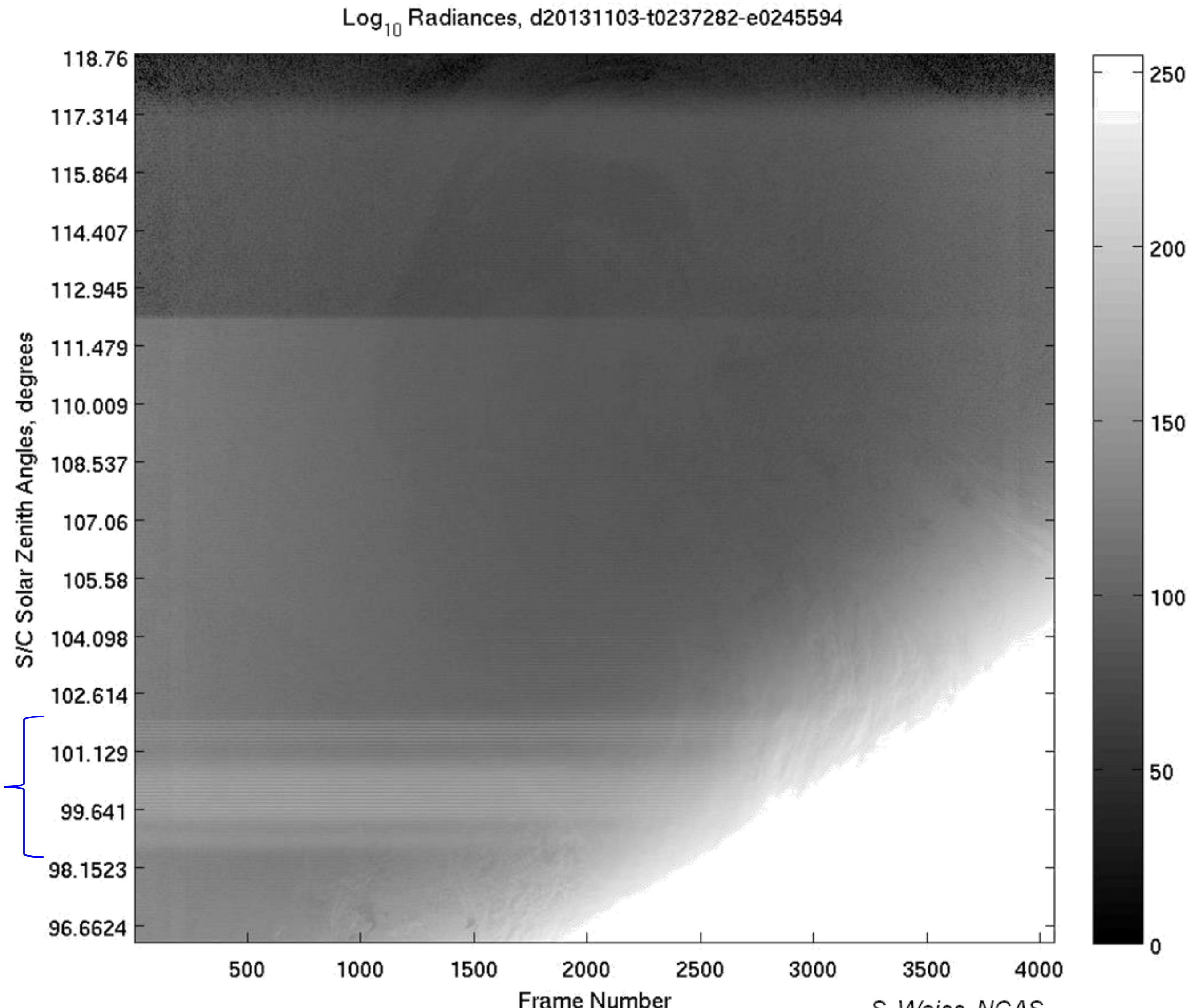

Additional stray light region ranges from S/C Solar Zenith Angles of about 102.3° to 98.6° for Nov 2013

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Corrected Radiances for Nov 2013 - Additional Stray Light Region Not Corrected

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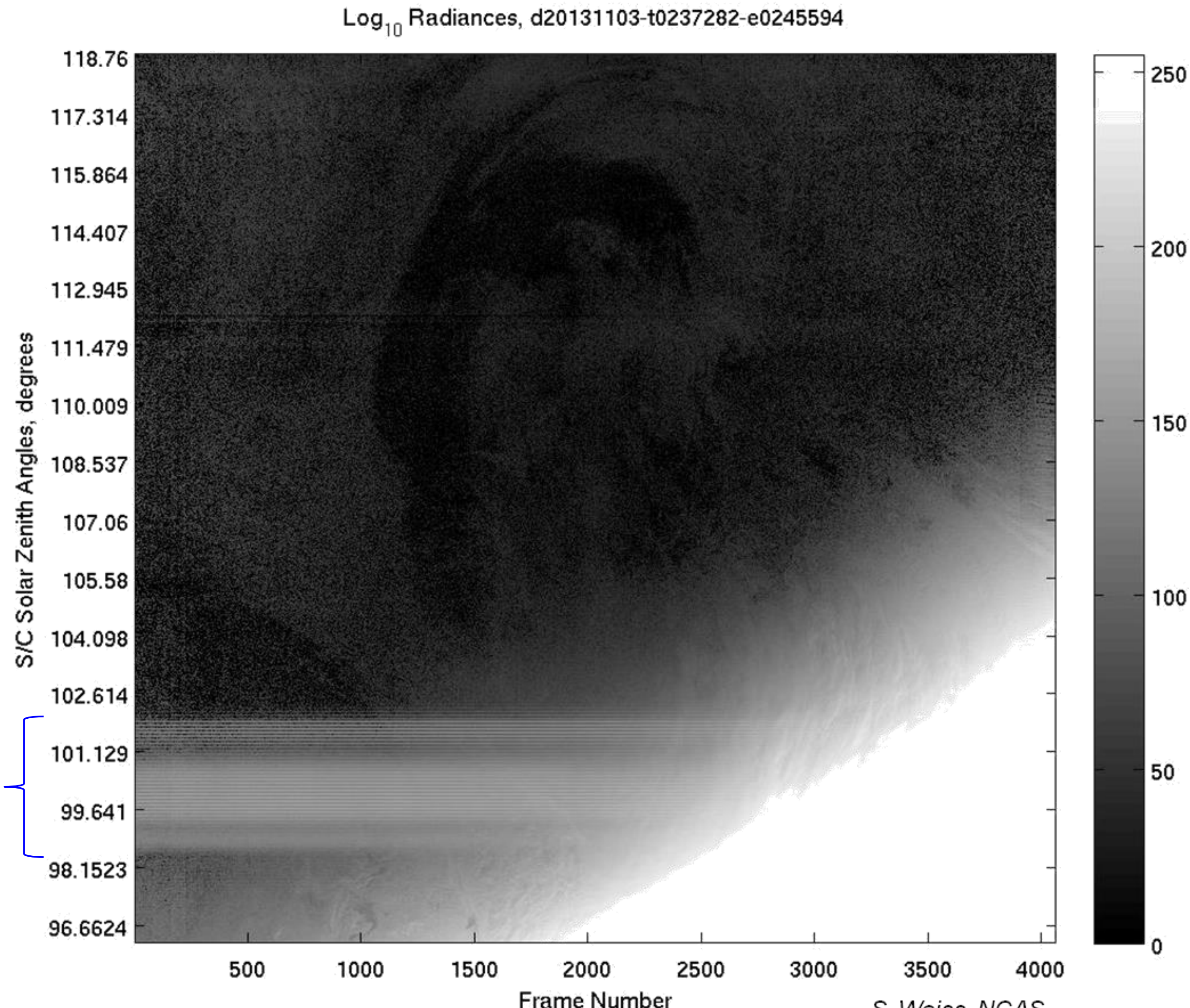
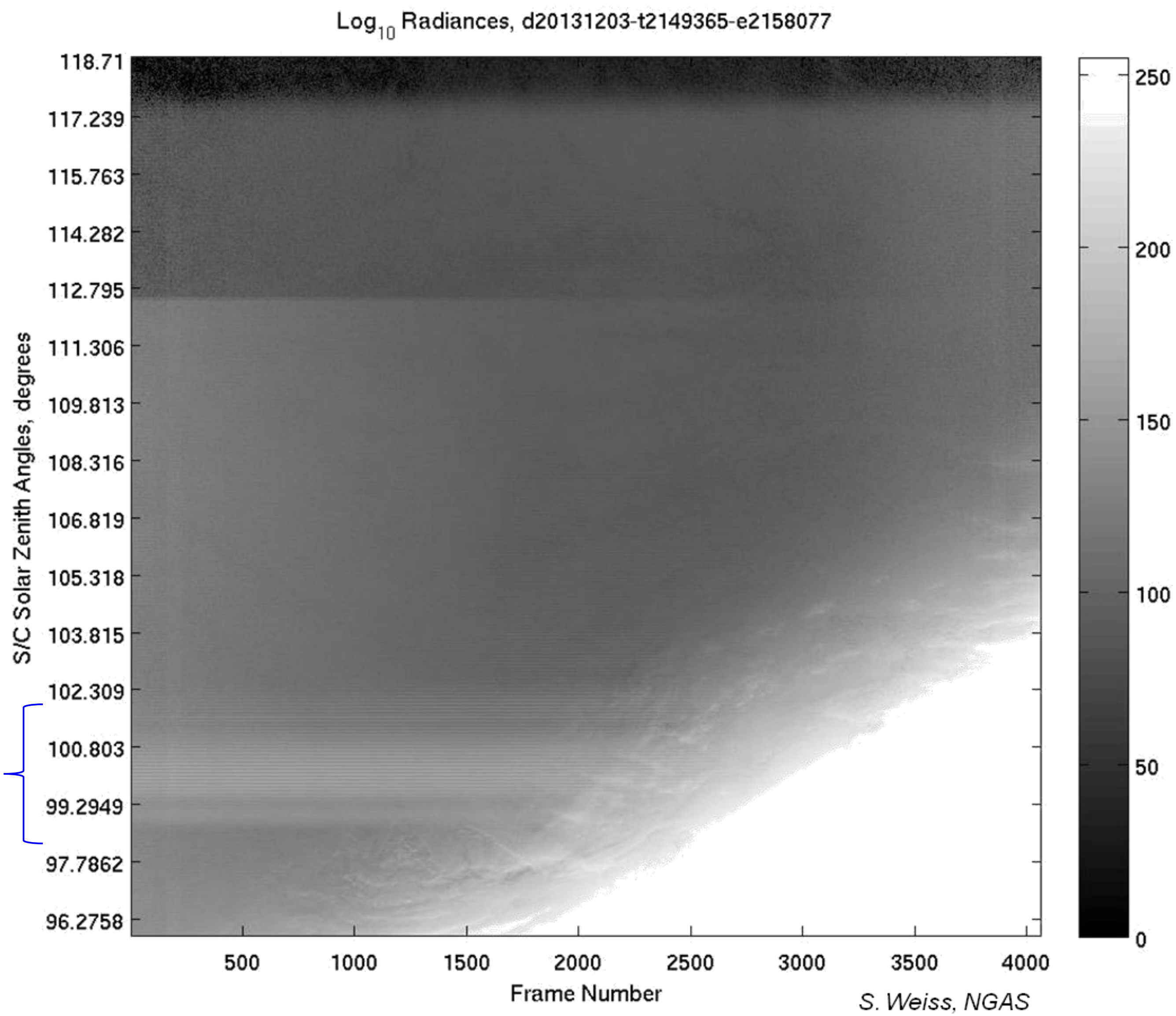
Additional stray light is not corrected by the stray light correction since this region is not modeled.



S. Weiss, NGAS

Uncorrected Radiances for Dec 2013 - Additional Stray Light Region Near Terminator

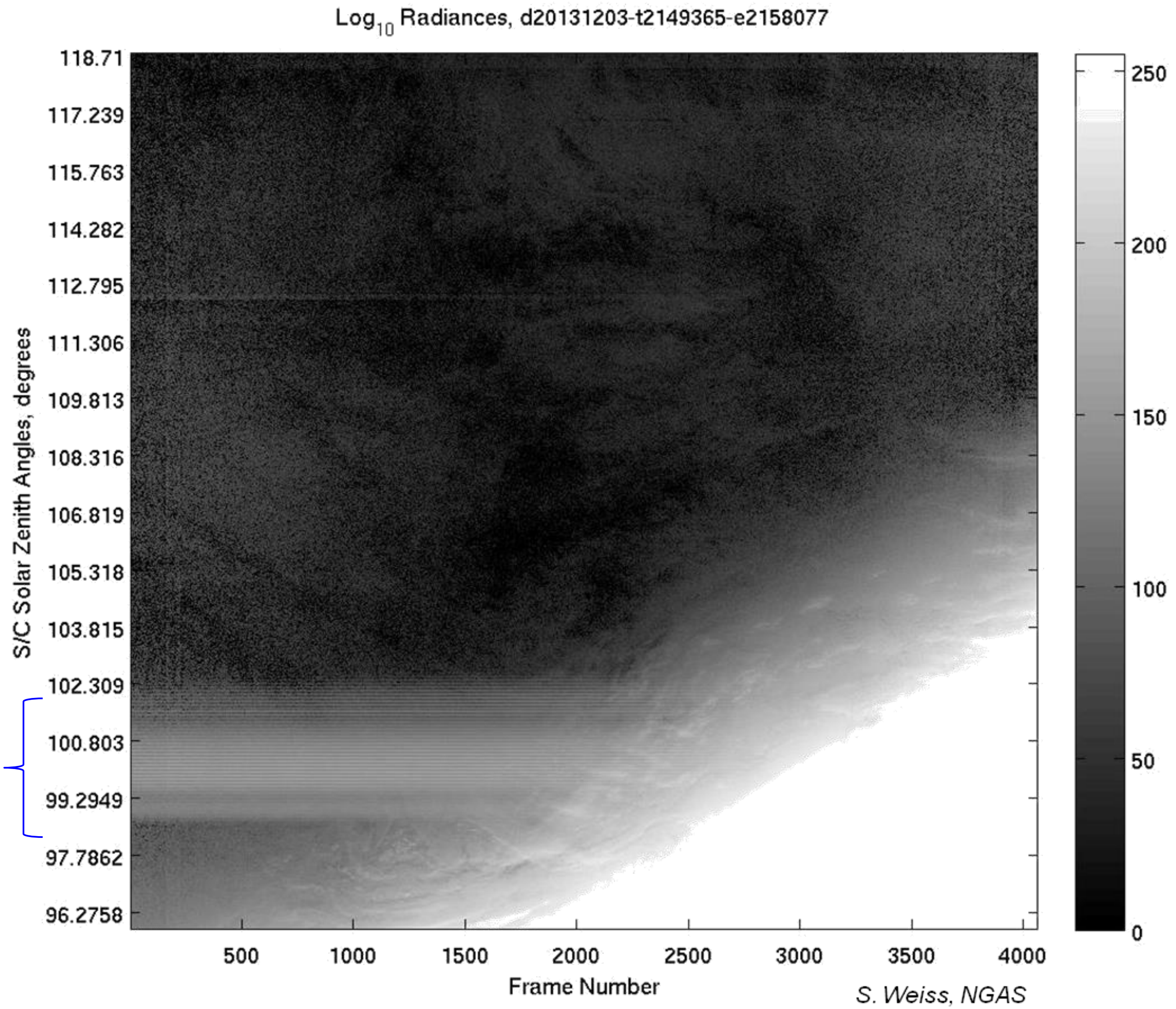
NORTHROP GRUMMAN



Additional stray light region ranges from S/C Solar Zenith Angles of about 102.5° to 98.9° for Dec 2013

Corrected Radiances for Dec 2013 - Additional Stray Light Region Not Corrected

NORTHROP GRUMMAN



Additional stray light is not corrected by the stray light correction since this region is not modeled.

S. Weiss, NGAS

THE VALUE OF PERFORMANCE.

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